Barrett (W. C.)

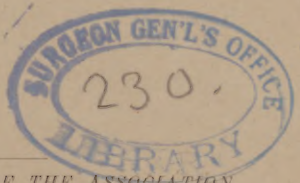
# ANÆSTHESIA.

BY

W. C. BARRETT, M.D., D.D.S., M.D.S.,

BUFFALO, NEW YORK.

READ BEFORE THE AMERICAN DENTAL ASSOCIATION, AT ITS TWENTIETH ANNUAL MEETING, HELD IN BOSTON, MASS., AUGUST 5TH, 1880.




*FROM THE TRANSACTIONS OF THE ASSOCIATION.*

PHILADELPHIA:
TRUSTEES OF SAMUEL S. WHITE.
1881.

# ANÆSTHESIA.

ALL through the centuries of time man has been endeavoring to find some way of escape from the penalties of broken law; to avoid the pain naturally consequent upon disordered function, or the lesions produced by accident; but until the nature and action of the so-called anæsthetics became known, his efforts were futile, or at the best but incomplete.

There are a number of different states which may be induced in which, while the condition remains, patients are insensible to pain, such as coma, syncope, anæsthesia, and sleep. The first three are pathological; the last is the normal condition of recuperation and recovery of wasted neural force. All these phases or conditions depend upon the nervous supply, and are induced by normal or abnormal nerve-currents.

There are certain drugs whose office seems wholly connected with the nervous system. Of these are nervous stimulants and sedatives, and a distinct class which are denominated anæsthetics. The mysteries of nerve force or of nervous supply have never yet been bared to human knowledge. We experiment and deduce so-called laws, but those laws are not general; they have so many exceptions that at present it is impossible to say how certain of these principles effect their marvelous purpose. Of some agents we know that their action is entirely reflex, and that the nervous system is affected through certain definite organs. But there are others of which this seems not to be true, and the scientific world is now engaged in the effort to solve this mysterious problem. So far, comparatively little progress has been made, and since the day of Claude Bernard, who advanced the theory that such agents as directly affect the nervous functions do it by a coagulation more or less complete of the protoplasmic ele-

ments of nerve tissue, nothing but barren hypothesis has been advanced.

Of the various impressions which medicinal agents may exert upon nervous function, let us confine ourselves to that state called anæsthesia, as the most important to the practitioner of dentistry, only considering stimulants and sedatives as they may be incidentally connected with our subject.

Narcosis or anæsthesia may be considered as a state of paralyzation of the sensory nerves, with insensibility or complete stupor. It is the suspension of sensation, and is the effect wrought by a number of agents, the most complete and powerful of which is hydrocyanic acid. But there are certain inciting agents or conditions aside from the direct action of drugs. In warm-blooded animals anæsthesia or insensibility to external impressions is produced by cold, or the lowering of the bodily heat, and in cold-blooded animals by the raising of the temperature. We are all familiar with the effect produced upon our own members by a long exposure to a low temperature, and we are conversant with the dreaded drowsiness which benumbs the faculties of a freezing person, which renders him insensible to pain and prompts him only to lie down and sleep. The same effects are produced upon a cold-blooded animal if the temperature be unduly raised.

EXPERIMENT 1.—Place a frog in a vessel containing water of 100° F., and it soon exhibits the same inertia and desire for sleep as the freezing mammal, and in a little time becomes quite insensible. If it be now removed to cold water it speedily recovers; but if long continued in the warmer fluid it dies.

The most common agents used to produce an artificial anæsthesia are nitrous oxide gas, chloroform, sulphuric ether, and bromide of ethyl. But carbonic acid, carbonic oxide, coal gas, olefiant gas, fumes of lycopodium giganteum, aldehyde, acetone, and other gases, when inhaled, may produce a like insensibility to external impressions. As, however, they are not commonly used to induce anæsthesia, we will not now particularly consider their properties.

*How* do these agents produce their characteristic effects? As I have said, this is a question which has not, so far, been satisfactorily answered. But, though no one can give an undisputed demonstration of their manner of action, there are certain phenomena the consideration of which may assist us in coming to some conclusion upon the subject, and these we will examine.

Claude Bernard says that an anæsthetic is a drug which produces a direct impression on nerve tissue. Prof. Anstie says that the pecu-

liar effects are through a modified blood-supply, or by alteration of nutrition, and most modern physiologists agree with him. Which is right? It is certain that anæsthetics are amenable to that law which is universal in therapeutics,—that to produce its characteristic effect a drug must be first introduced into the system, and that the method of its diffusion is through the blood.

EXPERIMENT 2.—Expose the lumbar nerves of a frog by raising the point of the sacrum. Pass a ligature around the whole body, excluding these nerves, and then inject the posterior extremities with woorari, or strychnia, or chloroform, and it will be seen that the anterior extremities are not paralyzed or convulsed, showing that the influence is not extended through the nerves.

To produce anæsthesia it is also quite true that there must be sufficient of the agent existing in the blood at one time. Ether and chloroform are eliminated almost entirely by the pulmonary mucous membrane. If of either a much more than sufficient quantity to produce anæsthesia be slowly injected directly into an artery, the characteristic effect is not seen.

EXPERIMENT 3.—Into the peritoneal cavity of a cat was very slowly injected ʒii of Squibb's chloroform, and the animal was but little affected. At another time I quickly injected ʒi of the same, and complete narcosis ensued.

When the drug is administered slowly the immunity is due to the fact that it is eliminated before it has time to exhibit its characteristic effect. Not enough is existent in the blood at one time to induce narcosis.

The most characteristic effects of common anæsthetics are produced when their vapor is inhaled, because it is thereby most readily introduced into the blood. The immense surface (about 1400 square feet) presented in the lungs of man brings the blood in osmotic contact with so much of the vapor that the pulmonary circulation is completely charged with it, and this is carried immediately to the heart, and thus distributed to the remotest part of the system without an opportunity being given for its elimination. But if an anæsthetic agent be injected into the venous circulation, little effect is produced, because it is carried directly to the heart, and from thence through the pulmonary artery to the lungs, where it is at once eliminated, never reaching the arterioles at all.

EXPERIMENT 4.—Into the jugular vein of a cat, previously anæsthetized, inject ʒi of sulphuric ether, and the animal will soon recover from the narcosis; while if it be injected into the carotid artery, it will deepen the influence.

We may then consider it demonstrated that the drug must be existent in the *arterial* blood in sufficient quantity at one time, in order

to produce its characteristic effect. Now follows the important question: Is it simply held in solution in the serum of the blood, or is it conveyed by the corpuscles? If the answer be, in the serum, that solves the problem at once; anæsthetics manifestly are agents which produce a profound impression directly upon nervous tissue.

But microscopic and other examinations show that anæsthetics change the character of the blood-corpuscles. You are doubtless all of you aware of the effect of carbonic acid upon the blood. It makes bright arterial blood dark in color. Carbonic oxide has a directly contrary influence, and changes venous blood to a bright red. If ether be mixed with blood, it gives it a dark-purple color. It prevents its re-arterialization, and, more than this, it changes the character of the blood-corpuscle. It dissolves it, and sets free the hematine. This phenomenon is less plainly seen in blood during its circulation, but it may be discerned even there. Chloroform turns the blood a brilliant scarlet.

Experiment 5.—Add the vapor of chloroform, or ether, or carbonic acid, or carbonic oxide, to a bottle partially filled with fresh venous or arterial blood, and then agitate it, when the change in color becomes apparent. To demonstrate the fact that ether or chloroform dissolves the blood-corpuscles, place a drop of blood upon a microscope slide, add to it a few drops of the fluid and place under a half-inch objective. Ether effects a solution much more readily than does chloroform.

We see, then, that CO and $CO_2$ are the direct antitheses of each other in changing the color of the blood. But this difference is not more marked than is that between sulphuric ether and chloroform. Alcohol causes blood to assume a brick-red color, and air will not again arterialize it. Yet the arterialization of blood is not a physiological process, but is quite mechanical.

Experiment 6.—Procure a quantity of defibrinated blood, anæsthetize a dog, and open the thorax. Bleed him to death by opening the carotid arteries, or by severing the aorta. Quickly dissect out and sever the pulmonary vein and artery, and, charging a large syringe with the defibrinated blood, inject it into the artery until it exudes from the vein, to clear the lungs of coagulum. Remove the lungs, with a part of the trachea, into which insert the nozzle of a bellows. Charge the syringe with the defibrinated blood again, and force it through the lungs, when the stream will not be changed in color. Repeat this, directing an assistant to keep the lungs filled with air by means of the bellows, and it will be seen that the blood is now arterialized, or changed to a bright red, the same as during life. But if, instead of forcing air into the lungs, nitrous oxide or the vapor of ether or chloroform be substituted, definite modifications of the color are produced.

[*Note.*—My observations on this experiment are not as full or complete as I hope to make them during the coming winter.]

It is then demonstrated that anæsthetics have the power to modify the ability of the blood-corpuscle to absorb oxygen. Is it in this manner that we are to account for the physiological effects of these agents? Let us examine some other conditions which in some of their phenomena resemble anæsthesia.

During sleep, as in anæsthesia, there is primarily hyperæmia of the brain, as may be indisputably demonstrated.

EXPERIMENT 7.—Anæsthetize a healthy dog, and over one of the hemispheres of the brain make a crucial incision through the scalp. Dissect the flaps back, and trepan, using extreme caution to avoid injury to the dura mater. The flaps are now secured and the animal allowed to recover. After two days, to allow ample time for full restoration, the dura mater is exposed and the animal again anæsthetized. During the earlier phases, and exactly coincident with the chloroform excitement-stage of narcosis, there may be observed a distinct tumor of the dura mater. When anæsthesia is fully established, this is reversed, and a depression exists where had been the protrusion. When this phenomenon has been sufficiently observed, the dura mater should be carefully removed and the wound secured by means of the flaps of the scalp. After another interval the animal should be again anæsthetized, when the brain itself may be studied, and its periods of hyperæmia and anæmia carefully observed.

Asphyxia presents many phases which are not unlike those of anæsthesia, and it is essential that we be enabled to clearly understand the difference between them. It is the result of a deprivation of oxygen, and its effects are mainly manifest upon the medulla. The lungs have nothing to do with the desire of a suffocating animal for breath, nor has the blood, any further than as that affects the medulla.

EXPERIMENT 8.—A dog was anæsthetized and a bellows ligated in the trachea, so as to entirely control the supply of air. As long as the lungs were kept expanded by the bellows, it is evident that there would be no attempt at breathing on the part of the animal. An artery was now opened, and the dog bled so nearly to death that the heart almost entirely ceased acting. Notwithstanding the fact that the lungs were kept fully inflated, *the dog now gasped for breath*, because, from the lack of blood-corpuscles to convey it, the medulla was deprived of oxygen. A tube from the carotid artery of another previously anæsthetized dog was now connected with the jugular vein of the animal, and transfusion was accomplished, the regular lung inflations of normal breathing being kept up by the assistant, who worked the bellows in the trachea. When functional activity was fully re-established and sensation of the medulla re-awakened, the thorax was opened and the lungs and heart exposed. The pneumogastric nerve was now divided, the left ventricle of the heart opened, and at the same time the pul-

monary artery ligated to cut off all blood supply to the lungs. It will be seen that the heart and lungs were now both isolated, or paralyzed, yet *the dog gasped for breath.*

As long as the medulla is supplied with oxygenated blood there is no effort or struggle for breath, even though other organs may be deprived of it, but the instant that this nervous centre is left without its needed supply there is a convulsive effort to breathe.

EXPERIMENT 9.—A bitch, two or three months pregnant, was anæsthetized and the uterus opened, exposing the quarter-grown fœtuses to the air. They manifested some uneasiness, but there was no symptom of any independent existence so long as the circulation of the mother was kept up. But when the umbilicus of any fœtus was severed there were shortly afterward convulsive efforts to breathe. This was constant with five of them. The sixth was not separated until after the death of the mother and the stoppage of circulation, when this fœtus also made the same efforts for breath.

In asphyxia the blood is dark in color, and there is the same anæmic condition of the cerebrum as in anæsthesia. The states of asphyxia and of anæsthesia are then analogous in many characteristic appearances, but I shall endeavor to show that there is a wide difference in their pathology; for while one is but the deprivation of oxygen, with the consequent characteristic effects upon the medulla oblongata, the other has added the positive presence of a toxicological agent which induces an added train of symptoms. The one is the cessation of function in the anatomical elements, the other is but a partial suspension in some of them. There are the same or analogous changes in the blood-corpuscles, and yet the pathological condition is widely variant. The one is the complete absence of oxygen from the medulla, the other is the possible partial oxygenation in the tissue elements.

Here, then, are two conditions analogous in their physical manifestations, both either produced by, or attended with changes in the blood-corpuscles, yet the one is entirely inconsistent with continued functional activity, the other quite compatible with life even indefinitely prolonged. This would seem to indicate that the suspension of sensation attendant upon both was due to widely different causes. At the outset of this paper, on the authority of Snow and others, I spoke of carbonic acid as an anæsthetic. This was not a mere inadvertence, but I did not desire to draw a distinction until it became plainly apparent. We now may see that, if I am correct, the two states are not identical. In fact, their nearest resemblance is that

both are conditions of insensibility; but on the same grounds a club may be denominated an anæsthetic, for its vigorous application will induce unconsciousness. We are then ready for a new definition, and an anæsthetic may now be denominated an agent which, existing in the blood in sufficient quantities, will produce insensibility to pain, and yet whose presence in such quantities is not incompatible with a continued existence. An asphyxiating agent is one which, while inducing entire unconsciousness, is incompatible with life. Now, as these two conditions are attended by the same physical symptoms, and are yet so widely variant, it would appear that they must be induced by different means. As asphyxia is demonstrably a change in the blood-corpuscle, it would seem that anæsthesia is due to some profound and specific effect produced directly by the agent itself. Herein the conclusions which I have reached are directly opposed to those of Snow, Sansom, Anstie, and most modern physiologists, who believe both asphyxia and anæsthesia to be due to a modified neural nutrition.

Let us look at the matter from another standpoint. I have spoken of the changes wrought in the hue of the blood both in asphyxia and anæsthesia, but it is now time to say that the alterations in color are not due to the appearance of either oxygen, carbonic acid, or any other agent. The changes are *induced* by them, but the diversity in color is merely one of form. Whatever tends to distend the corpuscles darkens the blood, owing to a change in its refractive powers, and the converse of this is also true. Thus carbonic acid distends the disks, carbonic oxide contracts them. Ether distends, and chloroform empties them, and accordingly under the influence of the former the blood becomes darker, while the latter makes it lighter in color. It is thus seen that changes in hue are not necessarily indicative of either the presence or absence of oxygen. It does not seem reasonable that the profound effects of anæsthesia are produced simply by a change in the *form* of the blood-disks. It cannot well be a lack of oxygen, for that is simply asphyxia. We must, then, come to the conclusion that the presence of the anæsthetic agent, as carried by the blood-corpuscle, does produce a profound impression directly upon nerve tissue, paralyzing it for the time, and making it incompetent to perform its proper functions.

This would seem to be the case, too, when we take into consideration the manner of progression of anæsthesia, which is from the extremities toward the central ganglions of the nerves. Anæsthetics also paralyze none but the sensory nerves. In both these character-

istics it is the direct opposite of woorari, which affects only the motor nerves, while its progression is from the centre toward the peripheries. These facts, too, seem inconsistent with the theory that anæsthetics produce their characteristic effects solely by the change in the nutrition of the anatomical elements of nerve tissue. Rather does it appear probable that their action is the invasion of a resistless enemy which, primarily attacking the outposts, where indeed it is first brought in contact with the filamental tissue, in its onward march lays its icy hand successively upon the delicate nerves, and rocks them in oblivion. Just what this power is, or in what peculiar manner it is exerted, we know not. We can study it only in the phenomena which it presents.

There are certain vegetable organisms which exhibit functions analogous to those of the nervous system of the animal world. The so-called sensitive plant presents a kind of embryonic or protoplasmic tissue which performs the physiological office of true nerve structure. *It is as easily anæsthetized as an animal*, and presents analogous phenomena when in an anæsthetic state.

Another reason why it seems to me incredible that anæsthesia is produced through a change in nutrition, is the fact that its agents affect nervous force when ordinary function and blood-circulation have ceased.

EXPERIMENT 10.—Remove the whole upper portion of the head of a frog, including cerebrum and cerebellum; open the thorax, take out the heart and lungs and cut off the extremities, leaving only the upper part of the alimentary canal. Two or three may be prepared in this way, when a smooth glass rod is thrust through each digestive canal, and its ends placed upon steady supports. It will now be found that the remaining portion of the frog will slowly travel along the glass rod, impelled by the vermicular motion of the œsophagus and intestine, and the ciliary motion of the larynx. But if a bell-glass be put over one of the frogs, and a sponge wet with chloroform be placed within it, this motion either ceases entirely or is materially retarded.

Surely this cannot be from any change in the blood-corpuscles, for their movements have ceased. But there is a persistence of nerve function, especially in cold-blooded animals, which does not cease when other functions are lost, but which, true to its law, is suspended by anæsthesia.

It seems to me unreasonable to suppose that anæsthetics should produce their characteristic effects through an altered nerve nutrition, when we remember how instantaneous is nerve action. Entire loss of sensation may be the result of a simple external nervous impres-

sion, as by fright, or shock; and this not through syncope, though an impression may be wrought through any of the senses which shall entirely suspend sensibility by means of a syncope,—itself merely the effect of a nervous impression. The sight of blood, the hearing of unwelcome news, the touch of a loathsome object, the taste of peculiarly unpleasant substances, or the memories revived through a penetrating odor, may instantaneously deprive a highly-wrought nervous organization of sensation, and induce complete syncope. Shall we say that these impressions are produced by an altered nutrition? It seems much more credible that they are the effect of direct shocks to the terminal nervous filaments themselves.

I now believe that I have produced sufficient testimony to justify me in seriously questioning the correctness of the conclusions of Anstie, Sansom, Snow, Duroy, Lallemand, and others, that anæsthesia is due to an alteration in the blood-corpuscles, or to a changed nutrition.

There are some phenomena presented in the action of the more common anæsthetics which are at least peculiar. While they all affect the sensory nerves alike, or produce the same general phenomena, their reflex effects upon the motor system and upon volition are widely variant. Chloroform and ether produce entire muscular relaxation. Nitrous oxide usually does so, but the administration of most of the other agents produces spasms, either tonic or clonic. At least this has been my own experience. Bromide of ethyl I have known to induce spasmodic action almost like that peculiar to strychnine poisoning.

Why is there almost an entire immunity from danger when chloroform is used in parturition? It would seem as if this agent were expressly intended for such occasions. There are analogous phenomena in alcoholism, as in the immunity from the effects of certain poisons which inebriates possess. These unusual phenomena can only be explained by supposing that nervous tissue is then in such a condition that it is no longer amenable to the profound direct impressions of the anæsthetic or toxicological agents.

Other reasons might be advanced for the faith that is in me concerning the physiology of anæsthesia, but they would be but a rehearsal of what has been better said by others, and I forbear. It appears to me that in this direction lies a wide field for scientific exploration. The speculations of late physiologists have, so far as I am concerned, but served to befog the whole matter. What the character of nerve force is no man can say. It resembles electricity,

but manifestly it is not that energy. That there is an impetus and flow to the mysterious impulse seems demonstrated, and its velocity has been measured, and found in man to be about two hundred and fifty feet per second, while in frogs it is about eighty. This rate of progression alone proves that it is quite distinct from electricity, even were it not true that there is in the nerves no such thing as a closed circuit, and that the mere injury to a nerve-filament stops the current, although there may be no solution of continuity. Neither can nervous force be accounted for on the hypothesis of chemical action, any more than by the supposition of the ancients that the nerves were hollow tubes through which flowed a nervous fluid. The whole subject is a mystery, even to the actual office of the nerves, for they are not essential to life, unless we except those which preside over involuntary muscular action, and the severing of these is only fatal after considerable time has elapsed.

Experiment 11.—Anæsthetize a dog and sever both pneumogastric nerves. It will be found that almost immediately the breathing and the heart-pulsations become irregular, at first increasing in frequency, but later becoming much retarded. The animal will exist for some days, and will finally die from other complications than the direct stoppage of the heart through want of nerve impetus.

That irritation of a nerve acts as a stimulus and sends some kind of an impulse along its course, we know; and that certain drugs, acting through other organs, produce a decided effect, either of stimulation or sedation, we also know. That there must exist a functional harmony in the system, so that increased muscular exertion will be at once provocative of an increased blood supply, is an evident fact, and it seems to be the office of the nerves to preserve this balance. When we are able to comprehend the character of this nervous force we shall better understand the therapeutical action of anæsthetics; and it seems to me that this very study of neurosis and neurotics is the paramount physiological and pathological question of the day.

## Anæsthetics.

The relative safety of the most commonly employed anæsthetics has been much discussed, and this goodly city of Boston has led the way in the indiscriminate denunciation of one agent as always unsafe, and the commendation of another as comparatively harmless. It must have been a model professional coroner's jury which arrived at this sage conclusion. That we cannot with impunity so far interfere with a normal existence as to suspend some of the most important

functions of life must be apparent to all. But the average student desires to know if there are degrees in the risk to be run, and if so, which offers the least peril. For all practical purposes we may ignore all anæsthetic agents save chloroform, ether, and nitrous oxide gas. A long series of experiments, closely observed for the purpose of obtaining illumination on this point, has failed to show any definite reason why one agent should be always chosen to the exclusion of others. At one time an experiment, repeatedly tried with the same results, pointed to a marked difference in certain physiological effects upon cardiac tissue in the administration of chloroform and ether, and I was fondly of the opinion that we stood upon the verge of a grand discovery. But another series, undertaken to fortify the ground I was about to assume and to make assurance doubly sure, overthrew my inchoate theory and again impressed upon my mind the fact that Truth does not reveal herself hastily to the experimental novice. The record of observations was thrown away, and I commenced back again.

The progression of anæsthesia is gradual. It does not overwhelm the whole nervous system at once, but it conquers by detail, and this seems to be the order of its resistless attack upon the great nervous centres:

First—The cerebral hemispheres.

Second—The spinal cord.

Third—The general ganglionic system.

Fourth—The respiratory ganglia.

Each of the agents exhibits certain characteristic phenomena in its action, yet all follow the same general law. Certain definite quantities of any toxicological agent may be tolerated by the human economy, but that point once reached and passed, the peril commences. Were this point of danger a definitely fixed one, we might know when it was approached and avoid exceeding it, but the line of safety depends greatly upon modifying circumstances. During digestion relatively large quantities of any poison may be ingested with impunity. A freshly-fed dog will endure a quantity of woorari that would be speedily fatal to one which was fasting. In producing narcosis we usually desire to anæsthetize the whole nervous system save that which presides over involuntary motion. The danger consists in going too far, and lest the point of safety be overreached, common prudence bids us proceed with caution. Air impregnated with deleterious gases may be inhaled, provided the proportion be not too great. Carbonic acid gas always exists in the atmosphere,

and unless the proportion exceed two or three per cent. it is harmless. Even as high as five or six per cent. is not specially injurious to the person accustomed to its inhalation, and Berzelius says that a man will live for some time in an atmosphere containing thirty per cent. of carbonic acid. Of carbonic oxide one per cent. is injurious, and can be inhaled for but a short time. Chlorine may be breathed in small quantities with impunity, notwithstanding the well-known acrid qualities of that gas. We see, then, that any gas may be so largely diluted with air as to fail to produce its toxicological effects. But there is a proportion beyond which we cannot go in the inhalation of any gas or vapor which will not support life. Exhaustive experiments have abundantly proved that not more than five per cent. of chloroform or ether can be breathed without extreme danger, and the observations of Lallemand, Perrin, and Duroy have demonstrated that an atmosphere of eight per cent. of chloroform is fatal, while two per cent. can be breathed a long time without inducing the anæsthetic state. That the great danger in the administration of any anæsthetic lies in allowing the patient to breathe an atmosphere too highly charged with the vapor is incontestably proved, and it must be accepted as a fact. I have not the time to enter into a further discussion of this subject, or to adduce the volumes of proof which are at hand, but the truth of the assertion is not disputed among experts in the administration of ether and chloroform. In the usual methods of giving these vapors a patient may easily be made to breathe an atmosphere of ten or even twelve per cent. What is the inference? *These agents should never be employed without the aid of an inhaler which may be implicitly depended upon to properly dilute the vapor.* In the use of nitrous oxide safety lies in withdrawing it before narcosis shall have proceeded too far.

In the use of chloroform, ether, and nitrous oxide there is a certain train of symptoms, each following the other with considerable regularity, but not, in the several agents, with the same degree of intensity. The first stage of anæsthesia is one of hyperæsthesia and excitement. There is an increased flow of blood through an accelerated action of the heart, and a dilatation of the capillaries, with contraction of the iris. This is especially marked in exhibitions of chloroform, and during its administration the excitement or hyperæsthetic stage is sometimes very violent; and it is at this time that the danger is particularly imminent in cases of lesions of the heart. Under the stimulus of the great sympathetic, if the muscular tissue

of the heart be weakened by fatty degeneration, or if there be marked diminution of its left ventricular capacity, its spasmodic struggles may result in an embolism when, as is usually the case, the muscular coats of the arteries are weakened through the irregular action of the heart, or that organ may itself become paralyzed through its extraordinary efforts to respond to the exertion demanded. Death then occurs either through spasm of the heart, or paralysis of the sympathetic nerve. The most reliable statistics show that more deaths occur at this stage of chloroformism than at any other, and I never heard of such an unfortunate termination in which the agent was not pushed beyond the bounds of prudence in allowing an atmosphere too heavily charged with the vapor.

Another symptom attending this stage, or immediately preceding it, is the choking sensation, or feeling of suffocation, attended frequently with violent coughing and spasmodic struggles for air,—another indication that the vapor is not sufficiently diluted. These symptoms may arise from two causes. I have in the first part of this paper shown that chloroform and ether modify the ability of the blood-corpuscle to absorb oxygen, and if the atmosphere be too highly charged with the vapor of either, the medulla soon manifests its imperative needs by spasmodic struggles for breath and by symptoms of asphyxia. The coughing arises from irritation of the terminal filaments of the glosso-pharyngeal nerve, as is proved by the loss of taste, and by the fact that if tracheotomy be performed and the vapor introduced through the tracheal tube, no such symptoms are ever observed. Any of you who have experimented with animals when the nozzle of a bellows was introduced into the trachea for the purpose of artificial respiration, and have anæsthetized the animal by means of a sponge applied to the valve, must have noticed this.

The next physiological sign in narcosis is contraction of the arteries, due to a still more profound impression upon the vaso-motor system, and the beginning of the loss of sensation in the extremities, as indicated by a tingling feeling in the fingers and toes, which gradually extends toward the vital organs.

If the excitement stage be once safely passed, chloroform narcosis proceeds quietly until the sensory nerves of the cerebro-spinal system are quite paralyzed, and if it be not pushed too far, the danger is very remote. If chloroform be properly administered and closely watched, it is not as dangerous as has often been represented; but its exhibition *absolutely demands* the services of a skilled expert, for as it is more powerful than any of the other agents, it requires greater care

on the part of the administrator. Especially should the iris of the eye be closely watched, for though in its later stages the pupil is expanded, caution must be observed that the total relaxation of coma be not approached. The danger is chiefly during the excitement stage, and then it is usually the result of want of prudence in allowing too great a proportion of the vapor.

In ether narcosis the excitement period is seldom attended with such violence as with chloroform, and hence there is less danger at this time, for the instances in which ether has proved fatal through paralysis of the heart are very rare indeed, if they exist at all. In all cases of death from ether of which I have any knowledge, the heart has pulsated some time after the cessation of breathing, but with chloroform it is the reverse. Ether, like chloroform, first stimulates the heart, but it does not seriously depress it afterward. The great danger in the administration of this anæsthetic is from the arrest of respiration, and this is due either to a paralysis of the sympathetic, or more often to the filling-up of the smaller bronchi by mucus, through the destruction of the sensibility of the membrane lining them, and the consequent cessation of the ciliary motion of the villi, which carries the mucus forward until expectoration can remove it. In nearly all cases of death from ether it will be found that bronchial râles and stertorous breathing precede death, the latter symptom being due to paralysis of the pharynx. By the expert the unfavorable symptoms from chloroform may be earlier and more surely detected than can those from ether.

The progress of narcosis, according to Anstie, is in its effects manifested—

First—Upon the cerebral hemispheres.

Second—Upon the cerebellum.

Third—Upon the medulla oblongata.

And the narcotized individual will lose—

First—Local sensibility in the extremities.

Second—The intellectual powers.

Third—The general power of co-ordination.

Fourth—Power of receiving sensory impressions.

Fifth—Power of breathing.

Sixth—Involuntary muscular action.

There seems to be, also, a general progress of anæsthesia through the cerebral nerves from the anterior portion of the brain posteriorly, for the first sense which is lost is that of smell, as is demonstrated by the usual demand for more of the agent, and this demonstrates a par-

tial paralysis of the first pair of nerves. This phenomenon is readily accounted for by the fact that the anæsthetic reaches the terminal filaments of the olfactory nerves before it is presented to those of any other, and is an additional argument in favor of the theory that anæsthetic effects are produced by a direct impression upon nerve filaments. After the loss of smell comes loss of sight, loss of ability to control some of the muscles of the eye, and an enlargement of the pupil, owing to paralysis of the ciliary and recti muscles, which indicates the overcoming of the third, fourth, and sixth pairs of nerves. About this time follows loss of sensation in the integument of the face and eyelids, of the muscles of the tongue and of the teeth, indicating paresis of the fifth. This is followed by loss of the expression of the face, and of hearing, denoting a paralysis of communicating nerves of the seventh and of the eighth, while the tenth, eleventh, and twelfth pairs of cranial nerves are the last to succumb.

Of nitrous oxide and the bromide of ethyl, time forbids me to speak extendedly. The first, the especial refuge of quacks, is of use only in brief operations, like the extraction of single teeth and the opening of abscesses. With the last my own experience has been anything but pleasing. In its administration to the lower animals, clonic spasms, sometimes of a very violent character, have induced too great a distrust of its safety to warrant me in giving it to human beings. There are many other things of which I would be glad to speak, and many experiments and vivisections which I have made, especially some illustrating modifications in the circulation of the blood, which I would desire to relate, but I spare you the recital.

My own experiments and observations in the use of chloroform and ether would lead me to use especial caution, in case of the former, to see that there had been no indication of weakened heart's action, as exhibited by fainting and dyspnœa; to use especial caution with those addicted to the use of alcohol, and to be particularly careful to give thorough dilution of the vapor until the excitement stage be passed. Finally, to carefully watch the later stages of anæsthesia, and to suspend the administration at the first indication of any excessive dilatation of the pupil, of stertorous breathing, or of relaxation of the muscles of mastication, as these are governed by nerves which arise from the medulla, and indicate danger to the sympathetic system.

In ether narcosis, instead of watching so carefully the action of the heart and the pulse, I pay particular attention to the respiration, and at the very first appearance of bronchial râles I suspend the administration. In case of the persistence of unpleasant symptoms from chlo-

roform, the utmost exertion should be put forth to stimulate the heart to action, such as the administration of arterial stimulants, electric currents, and nerve shocks. If the danger occurs in ether narcosis, pay little attention to the heart or pulse, but commence artificial respiration, and persist in it until long after hope shall have almost fled. Several instances are on record where artificial respiration, after the methods recommended by Marshall Hall or Dr. Silvester, has resulted in recovery long after the patient had been pronounced irrecoverably dead. In both cases keep up the temperature by artificial heat. Many a life has been lost which might have been saved only for allowing the temperature to be reduced by the subsidence of functional activity. In any case, a cool head and the possession of all your faculties, with perseverance in the use of restorative measures, will enable you to overcome the most determinedly adverse symptoms, and prove you worthy to be trusted in the gravest complications.